

Climate analogues tool

an approach to mitigate climate change

U P Faras Bin Muhammed¹, K Kandiannan² and K S Krishnamurthy³

ICAR-Indian Institute of Spices Research, Kozhikode, Kerala 673 012

Climate analogues approach allows researchers to identify, connect and map sites with statistically similar climates across space and time. The approach has the potential to be applied in agricultural policy and planning and provides a novel way to support climate change adaptation in the agricultural sector. Climate Change, Agriculture and Food Security (CCAFS) have provided an online platform (the Climate Analogues Tool) for quick, easily accessible and user-friendly applications of the Climate Analogues approach.

Key words: Climate analogues, Climate change

CLIMATE Analogues tool is used to identify areas that experience statistically similar climatic conditions, but which may be separated temporally and/or spatially. In essence, the approach allows us to glimpse into the future by locating areas whose climate today is similar to the projected future climate of a place of interest or vice-versa.

Direction of analysis: The tool allows researchers to identify analogues sites in three directions.

Backward direction: Future climate of the reference site is compared with the present climate of all other locations in the search range, viz. Where can I find sites at present that are climatically similar to how my site is projected to be in the future? (Future→Present)

Forward direction: Present climate of the reference site is compared with the future climate of all other locations in the search range, viz. Where can I find sites in the future that will be climatically similar to how my site is at present? (Present→Future).

None direction: The present/future climate of the reference site is compared with the present/future climate of all other locations in the search range, viz. Where can I find sites at present that are similar to my site? Or, where can I find sites in the projected future that will be similar to my site in the projected future? (Present→Present/Future→Future, no temporal direction).

STEPS TO USE THE TOOL

Step 1: Selection of location

Selection of reference site

The reference site is the location for which we want

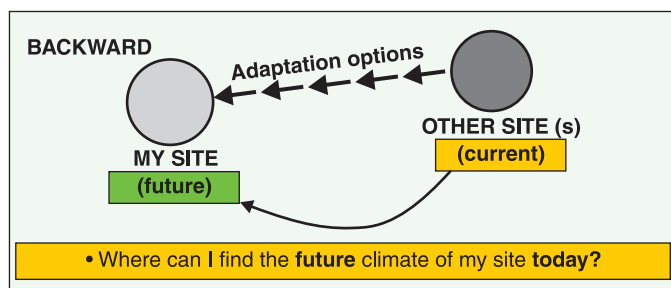


Fig. 1. Backward direction

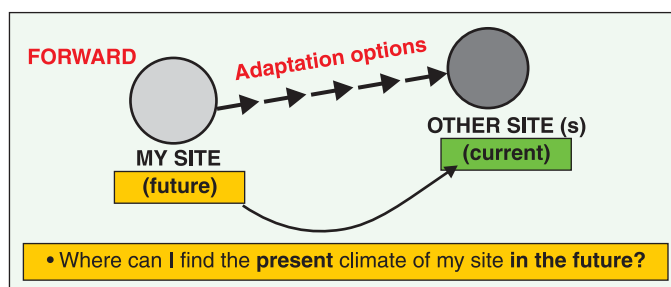


Fig. 2. Forward direction

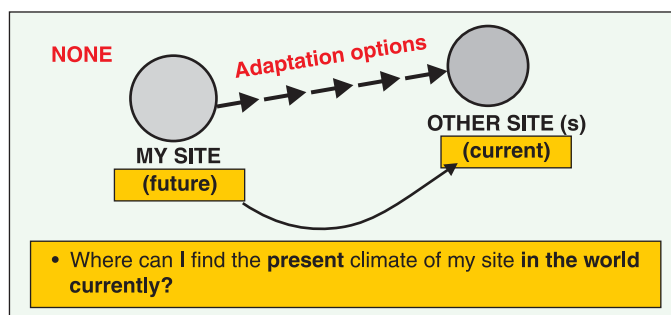


Fig. 3. None direction

Fig. 4. Selection of the reference site and search range.

to find analogues climates, viz. when we want to find analogues climate place say, Dindigul, a district located in Tamil Nadu, the reference will be Dindigul. The reference site may be located within any land area. To run the analysis, the geographic location of the reference site has to be indicated first. This can be done either by manually entering the latitude and longitude coordinates into the appropriate boxes or alternatively we can click on a location on the map to generate the coordinates for example, by entering the coordinates of Dindigul in appropriate boxes or we can click on Dindigul on the map to generate the coordinates. The red target displayed on the map marks the reference site that will be used for the analysis (Fig. 4)

Selection of a search range

The search range is the geographical area within which we want to find analogues sites. Hence we need to designate the search area within which we want to find analogue sites

If we select the “global” search range, the tool will look for climate analogues across all land areas in the world excluding Antarctica (i.e. -60 to 90 degrees latitude, -180 to 180 degrees longitude). If we are unsure where we expect to find analogue sites, the global search range may be a good starting point from which we can narrow our search later.

Alternatively, we can also select a specific country or continent in order to focus the climate analogues search, speed processing time and produce results with a higher resolution, viz. to find the analogues climate of

Dindigul in India, we can select the search range limited to India or to find in other countries, we need to specify the country in which we are interested to locate the analogues sites.

Step 2: Selection of direction and global climate models

Variables required

Direction: The direction in time to run the calculation relative to the reference site.

Here, we must define the temporal parameters for the analysis. First, we need to define the *direction* in time in which we want to run the analysis. The direction is very important because depending on which direction we choose; the tool will produce different results with quite different interpretations. Three direction options are available (Fig. 5).

A *backward analysis*, in which the future climate of the reference site is compared with the present climate of all other locations in the search range,

A *forward analysis*, in which the present climate of the reference site is compared with the future climate of

all other locations in the search range, or

A *non-directional analysis (none)*, in which the present/future climate of the reference site is compared with the present/future climate of all other locations in the search range.

Period: The time period over which average climatic conditions are calculated.

Scenario: The Special Report on Emissions Scenarios (SRES) scenario used to predict future climatic conditions.

The baseline climate is calculated over the period 1960-1990 which is a commonly used reference period for future climate studies. Currently future climate forecasts are limited to the 2020-2049 time periods (i.e. the climate of the 2030s decade), however more options that forecast further into the future are to be added to the online tool. If we are performing a backwards or forwards analysis there are three emission scenarios to choose from: A1B, A2 and B1. Each emission scenario describes future projected greenhouse gas emissions when global development proceeds with varying emphasis in areas of social and economic development, i.e. between globalisation vs regionalisation, and between an economic vs environmental focus. For example, emissions scenario A1B is an intermediate scenario which describes a future world of very rapid economic growth, low population growth and rapid introduction of new and more efficient technologies. As the future projected greenhouse gas emissions under each scenario vary they thus produce different projected future climatic conditions.

Fig. 5. Selection of the direction of analysis and future climate scenarios

Model: It refers to the global climate models (GCMs) used to predict future climatic conditions.

Resolution: The pixel size of input and output rasters.

We need to select the global climate models (GCMs) that will be used in the analysis. It is possible to choose between the individual GCMs for each emission scenario or an ensemble which uses the average of all available GCMs. Results will vary slightly with each GCM. Generally, to decrease the uncertainties of GCMs, the ensemble option is preferred. However, in order to observe GCMs uncertainties, we can run each GCM separately and compare the results.

When applicable, we may also select the *resolution* of the sites. Resolution refers to the pixel size of the input and, subsequently, output rasters. By selecting pixels of a smaller size (e.g. 30 arc seconds versus 10 arc minutes) the resolution of the results map will be increased but this comes at the cost of an increase in processing time. A 30 arc-seconds is approximately 1 km when measured at the equator while 10 arc-minutes is approximately 19 km.

Step 3: Select climate variables and define other analysis settings

Variables required

Climatic and bioclimatic variables: Input climate data used to calculate climatic similarity.

Weights: It allow the adjustment of the contribution of each variable to the final similarity measure.

Two types of variables are available for selection: climatic, which refer to monthly precipitation and mean temperature, or bioclimatic, which include 19 variables that describe in detail the seasonality, extremes, and climate averages of sites. A maximum combination of three variables may be selected simultaneously for each analysis (Fig. 6).

There is also the option to *weight* the variables according to the importance we want to give them in the analysis. If we do not have insight into the importance of each variable in the search area, it is suggested to first use equal weights of “0.5” for both temperature and

Fig. 6. Types of climate variables, rotation, growing seasons and thresholds

precipitation in order to first observe these preliminary results. If one variable is known to be more influential we can modify the weights for temperature and precipitation, giving weightage to the more influential variable.

Rotation: Data may be rotated using a Fourier transform to compensate for effects of seasonality.

The rotation allows us to compensate for the fact that rainfall events and temperature seasonality do not occur at the same period of the year in the northern and the southern hemispheres (as well as other less distinct, but equally important, regional variations). By selecting a rotation, the tool will shift (rotate) the climatic data variables for all locations in the search range to align the underlying trends in the data and eliminate the effects of seasonality. We are free to experiment with the rotations, but it is recommended rotating by precipitation in tropical and subtropical locations where there is little seasonal temperature variation but the timing of the rainy season may have large agronomic implications, and by temperature at higher latitudes where large seasonal variations in temperature may be observed, i.e. summer versus winter temperatures.

Temporal scale: The months of the year (growing season) that we want to focus the search on.

If the interest is in a specific crop, this period can be defined in terms of the crop's growing season. Up to two time periods can be specified and only the months falling within these time periods will be considered when calculating the climatic similarity of

the sites. E.g. in Fig. 6, the specific temporal scope is chosen from May to August. If we are interested in analyzing the entire year, and do not want to specify a growing season, leave the temporal scope set at 1 to 12 i.e. January to December.

Threshold: The minimum level of similarity that will be displayed on the results page.

Finally, a threshold value can be defined to restrict or filter the results of the analysis to only the most similar sites. i.e. selecting a threshold of 0.5 will result in only those sites with a similarity measure greater than 0.5 being displayed on the map.

Once all parameters are set, click on the *Run Analysis* button to begin the calculation. The calculation starts by loading the reference site data during ‘training’, continues by loading the weights, and then calculates the dissimilarity values between the reference site and all other sites within the search range. Depending on the climatic variables chosen, number of GCMs, the resolution chosen and size of the search range chosen results may take between 1 and 15+ minutes.

Step 4: Selecting candidate analogues sites

The results are displayed on a basemap in discrete colours from low to high climate similarity with the reference site represented by the target symbol (Fig. 7). If a threshold value was chosen only those sites whose CCAFS similarity statistic exceeds that value will be shown. We may zoom to investigate a specific area of interest, view results on a larger map and also print a summary report of our results.



Fig. 7. CCAFS climate similarity results projected onto a map in the online tool

- Turn on/off layer. Makes layers visible/invisible in the map window.
- Zoom to layer. Zooms to the search area specified for this run.
- Adjust the opacity of this layer. Allows for the results of more than one analogues run to be viewed simultaneously.
- View the parameters used to obtain this result. Displays relevant information for reference site and search range specifications as well as climate variables used.
- Code to use in R. Displays the equivalent R code that could be used to replicate these results locally if supplied with the correct input data.
- Save these parameters. Saved parameters may be reloaded at Step 1, removing the need to reenter the parameters
- Download the results in GeoTIFF format for further analysis or display in other platforms.
- Remove this result. Deletes map layer and all unsaved run information.

The results page also provides a number of options to assist in visualizing the results and identifying candidate analogue sites:

Upon finishing our first analysis, we can make additional runs by returning to the *Step 1. Select our location* window or alternatively *Step 2* or *Step 3*. To save time the parameters used during the previous run remain loaded, so only the variables we wish to change need to be modified.

SUMMARY

This tool is very useful in identifying the analogues sites. This may be more helpful for such species/crops whose productivity is sinking due to climate change as this tool can help in identifying favourable areas for cultivation in other parts of the country/globe where the climatic conditions are suitable, so that the production can be enhanced. For more details, please refer to website: <http://analogues.ciat.cgiar.org>.

¹Senior Research Fellow, ^{2,3}Principal Scientists, ICAR-IISR, Kozhikode, Kerala. Corresponding authors' e mail: farasmuhammed.313@gmail.com

Evolutionary Algorithms

DNA of organisms on earth is thought to have evolved in 3.5 – 4.6 billion years. Three major processes of evolution are selection, recombination and mutation. So, the world around us is a result of billions of generations of recombinations, mutations and selections over a population of billions. As a matter of fact, unconstrained methods employed by nature are too slow to solve our problems. Genetic algorithms are a class of algorithms that are inspired by Charles Darwin's theory of Evolution. A competent Genetic Algorithm is centred around decomposing problems into sub-problems, finding solutions to those sub-problems and combining them to build the solution.



Compiled by: Dr Himanshu Varshney, Scientist, ICAR-DKMA, himanshu@icar.org.in